

Spacecraft Systems & Missions: Payloads and Spacecraft

Summary

This 4-day course is for technical and management people who want to remain up to date on spacecraft design for both the conventional missions and the small-sat applications to communications, remote sensing, and science. The design constraints imposed by the launch and on orbit environments are covered. Spacecraft platform design principles and tradeoffs are explained with illustrative examples: structure, power, thermal, data communications, and TT&C. Big-system and small-sat payload applications and design are covered. Design issues such as weight, cost, and reliability are covered with "how-to" examples. Current trends in design choices, qualification and testing are discussed.

Extensive use of real examples permit easy understanding of the systems selection criteria, relationships and interfaces which are all part of the design process. All important subsystems will be addressed and their key relationships and interface requirements discussed. Examples will begin with the general requirements and proceed with complete weight and power specifications.

This material is recommended for professionals interested in current space system developments for commercial and scientific applications while acquiring a broader background in the design, development, and use of spacecraft. The instructors use demonstrations, simulations, and real examples to illustrate important points. All attendees receive an extensive set of notes.

Instructors

Thomas S. Logsdon has accumulated more than 30 years experience with McDonnell Douglas, Lockheed Martin, Boeing Aerospace, and Rockwell International. His research projects and consulting assignments have included the Apollo moon flights, Project Skylab, and variety of interplanetary missions. Mr. Logsdon has worked on the Navstar GPS Project including constellation design and coverage studies. He has taught and lectured in 24 different countries on six continents and he has written and published 1.7 million words, including 29 technical books. These include *Striking it Rich in Space*, *Understanding the Navstar, Mobile Communication Satellites*, and *Orbital Mechanics: Theory and Applications*.

Edward L. Keith is a multi-discipline Spacecraft and Launch Vehicle System Engineer, specializing in integration of technology, design, modeling and business strategies. He is an independent consultant, writer and teacher of space and rocket system technology. He is experienced in spacecraft and launch vehicle operations, design, testing, business analysis, risk reduction, modeling, safety and reliability. Mr. Keith's experience extends to both reusable and expendable launch vehicles, as well as to both solid and liquid rocket systems. Mr. Keith has designed complete rocket engines, rocket vehicles, small propulsion systems, and composite propellant tank systems, especially designed for low cost, as a propulsion and launch vehicle engineer. Mr. Keith has worked the Space Launch Initiative and the Liquid Fly-Back Booster programs for Boeing, originated the Scorpius Program for Microcosm, worked on the Brilliant Eyes and the Advanced Solid Rocket Motor Programs for Rockwell and worked on the Aerojet Launch Detection Satellite program. He also has 13-years of government experience including five years working launch operations at Vandenberg AFB. Mr. Keith has written 18 technical papers on various aspects of low cost space transportation over the last decade.

Course Outline

Introduction - The Science of rockets, space missions, space, exploration and exploration, commercial ventures, and national security missions is introduced in the context of modern spacecraft and payload design. The major functions of a spacecraft bus, power, communications, propulsion, attitude and thermal control, are introduced.

Orbital Mechanics – A historical perspective of Kepler's Laws and Newton's Generalizations is presented. Orbits as conic sections and ballistic trajectories are described. The critical importance of velocity and the issues of weightlessness are discussed.

Satellite Orbits – Issac Newton's Vis Viva equation is examined. The issues of Reaching escape velocity, lunar trajectories, orbital energy and angular momentum are presented. Escaping from an elliptical orbit and the concept of gravity wells are studied. Kepler's equation and the six classical orbital elements are

explained. The effects of launch azimuths on orbital inclination and ground trace geometry are presented. The forces of perturbations are described.

Booster Rockets - Launch Vehicle issues for spacecraft designers are introduced. The environments of ascent, including g-loads, vibration, shock events, acoustic noise, air-venting, accelerations, and ascent trajectories are defined. Solid and liquid systems rocket are explained, including staging issues. Elements such as fairings and payload deployment mechanisms are explored.

Propulsion – Rocket propulsion requirements for spacecraft applications are explained, including fundamentals of propulsion, thrust, specific impulse, total impulse, Delta-V calculations with the rocket equation and propellants. Storable catalytic mono-propellant, bi-propellant hypergolic systems and cold gas systems used on modern spacecraft are explored in greater depth.

Orbital Environments – The issues of atmospheric density and orbit decay is explored. The Earth's gravitational field and gravity gradient stabilization are described. The South Atlantic Anomaly is defined and understood. Meteoroids in space and manmade space debris in the context of spacecraft survival are covered.

Powered Flight Maneuvers – The Hohmann Transfer Maneuver as the most efficient transfer between coplanar orbits is described. Low thrust maneuver between orbits and plane change maneuvers are studied. Relative motion equations and rendezvous techniques are covered. Maneuvers to de-orbit spacecraft are discussed. Swing-by maneuvers are explored in an easy-to-understand format.

Systems Engineering - Introduction to basic Mission design. Examination of the Spacecraft Mission life-cycle is explored. Understanding of required milestone Reviews, requirements and basic Systems Engineering is reviewed in the context of Spacecraft Design. Technology readiness levels are introduced in the context of design risks.

Attitude Control - Spacecraft attitude fundamentals are explained, including coordinate systems, Angular momentum, Environmental disturbances and torques. Attitude sensors and attitude control techniques are explored. Special devices such as reaction rockets, Reaction wheels and magnetic torque devices are introduced. Fundamentals of spinning spacecraft are explained.

Charged Particles in Space – The energy levels of charged particles in space are described. The Solar Winds, solar proton flairs, cosmic rays, the Van Allen radiation belts are covered. The Earth's Ionosphere and the Auroras are explained

Orbit Selection – Choosing the proper orbit is explored. Constellation selection concepts are stated. John Walker's contributions are presented. John Graim's approach is described. Mobile communications satellites are explored. Simulation techniques and Trades are presented. The fundamentals of Satellite horizon, fields of views, ground track, swath coverage and repeating orbits is covered.

Reliability and Risk Management – Classical Reliability theory and practice is contrasted with realistic reliability expectation for spacecraft design. Issues of redundancy to increase both reliability and mission lifetime are introduced. Modern risk management, especially with new technology, is examined.

Communications - Introduction to Spacecraft uplink, downlink and crosslink Communications used on spacecraft, including bandwidth, power requirements, antennas and gain, losses, noise devices and Modulation techniques. The role of modern Ground Stations to support mission success is described.

Advanced Propulsion - Solar-electric propulsion is introduced. Electro-magnetic catapults, nuclear propulsion, laser powered rockets, tethered satellites as alternatives to conventional propulsion are described. The concept of stationary and rotating skyhooks are explored.

Case Study – GPS Radio Navigation Systems - Radio navigation techniques are described, including space-based radio navigation. The GPS system is described, including on-orbit maneuvering techniques.

GPS orbital perturbations are explained. The methods of computing the satellite position is described. The orbital geometry of the GPS constellation and typical GPS applications are explained.

Spacecraft Power Systems - Spacecraft Power System elements, including solar cell panels, batteries, power requirements, and Radioisotope thermal generators (RTG) are introduced. Sizing power systems for changes over time that account for end-of-life of spacecraft operations requirements are explained.

Spacecraft Propulsion – Spacecraft propulsion subsystem elements for delta-V maneuvers, station-keeping and attitude control are explored, including redundancy and lifetime management. Electric propulsion for deep space and station-keeping purposes is discussed along with a brief introduction to nuclear propulsion.

Wrap Up - The direction of future spacecraft design, technology and missions are explored to conclude the lessons of modern spacecraft design.

What You Will Learn

- Latest developments in satellite applications to low-orbiting constellations, satellite navigation, and geostationary communications platforms.
- Fundamental satellite design processes and examples.
- All important satellite subsystems and their interactions.
- Orbital maneuvers and propulsion system requirements.
- Integrating payloads into the spacecraft.